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# The Mushroom Mite (*Tyrophagus lintneri* (Osborn)) as a Pest of Cultivated Mushrooms<sup>1</sup>

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## SUMMARY

This bulletin deals with the life history of the mushroom mite *Tyrophagus lintneri* (Osborn) under controlled temperatures and gives notes on its prevention and control in mushroom houses.

This mite is a pest of mushrooms and to a lesser extent of cheese in storage and in granaries and mills. In the mushroom houses the mites eat the spawn and make holes in the stems and caps of the mushrooms.

There are three immature stages between the egg and the adult mite.

Mites were reared in cells at three temperatures. A temperature range of from 75° to 78° F. represented the temperatures in a mushroom house during the first 2 weeks of the spawn run, 65° represented that during the later spawn run and the casing period, and 55° that

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<sup>2</sup> Died January 4, 1942. With the death of the author, the manuscript was prepared for publication by C. A. Weigel and L. B. Reed.

during the period of the harvest. At the three temperatures mite development required 12, 19, and 54 days, respectively.

The adults may live over a year at 55° F. and as long as 209 days at 76° F. The ratio of the sexes is about 42 percent males to 58 percent females. The females normally lay only fertile eggs. They do not oviposit before mating but begin soon after mating and continue egg laying through most of the remainder of their lives.

At 55° F. a new generation may begin every 2 months, with consequent overlapping of generations.

Since the mites are probably brought into the houses with the compost, control measures include obtaining manure from stables kept in a sanitary condition and removing the spent compost to a distance from the mushroom house. The proper composting of the manure and heating of the beds and fumigation with either hydrocyanic acid gas or sulfur dioxide at "peak heat" are standard control measures. Nicotine and pyrethrum applied to bearing mushroom beds gave good results. Promising results were obtained with drenches containing dichloroethyl ether and methyl salicylate. Flame treatments, boiling water, and live steam may be used between the flushes of growth to kill the mites on or very near the surface of the beds.

## INTRODUCTION

The mushroom mite (*Tyrophagus lintneri* (Osborn)) is one of the most important pests of cultivated mushrooms in the United States and Canada. It frequently occurs in enormous numbers in mushroom houses, where its control is extremely difficult and where it is capable of ruining the crop.

Most of the biological studies reported in this bulletin were made at Beltsville, Md., from 1935 to 1941, inclusive.<sup>3</sup> The purpose was to determine the life history and habits of the mite with particular reference to such phases as could be utilized in measures to prevent the occurrence of large numbers in mushroom plantings.

## HISTORY AND DISTRIBUTION

The mushroom mite was described by Osborn in 1893 (21)<sup>4</sup> from specimens submitted by J. A. Lintner, who reported it as infesting mushrooms at Jamesport, Suffolk County, N. Y. Since that time it has caused damage to cultivated mushrooms in various places in the United States and Canada.

The mushroom mite and several related species have been known for a long time as pests in mills, granaries, cheese storerooms, and other places where food is kept. As a pest of mushrooms it has not been so important in recent years as previously, but sporadic outbreaks are to be expected.

*Tyrophagus lintneri* was once an extremely serious pest in the mushroom-growing district of Pennsylvania, but, although a few mites can always be found, a serious infestation has not been seen in that region since 1934 or 1935. This may be largely attributed to

<sup>3</sup> The studies on control were begun by E. A. Gahm at Arlington Farm, Va., in 1929 and were taken over by A. C. Davis under the supervision of C. A. Weigel in 1931. The work was transferred to Beltsville, Md., in 1935 and continued after the author's death in the early part of 1942 by C. A. Weigel and J. D. De Coursey.

<sup>4</sup> Italic numbers in parentheses refer to Literature Cited, p. 25.

better sanitary conditions throughout the industry, but it is entirely possible that relaxation of vigilance would result in a return of the former condition.

### FOOD HABITS AND INJURY

*Tyrophagus lintneri* is recorded primarily as a pest of mushrooms. It has been found attacking cheese in storage, and in the laboratory may be reared in great numbers upon a variety of organic materials such as dried fruit, grain, and tobacco stems. As a general thing the mites prefer foods that are relatively moist, or in which molds have begun to develop. It is probable that in a wild state they are primarily feeders upon decaying plant material and wild fungi. Their liking for fungi and their ability to survive and reproduce in places



FIGURE 1.—Typical injury to mushrooms by the mushroom mite (*Tyrophagus lintneri*).

where edible fungi are artificially grown brings them into direct competition with man in the mushroom industry.

In the mushroom beds the mites feed on the mycelium, or "spawn," in the compost and on the mushrooms (sporophores) themselves. Where the mites are not very numerous the damage may be slight, and their presence may be completely overlooked. The damage done to the spawn by even a fairly heavy mite infestation is not very apparent at first, and the resulting reduction of the crop may be attributed to some other cause. Later, however, the absence of mycelial threads in the compost is noticeable. The damage to the mushrooms consists of irregular holes eaten into the caps or stems of the larger mushrooms (fig. 1) and sometimes the complete hollowing out of the small "buttons." The holes may be large and are usually slimy within, or contain smaller individual feeding pits, which are slimy at their bottoms. On close examination each hole will be found to contain mites, sometimes a great many. In some cases there may be hundreds or even thousands of mites on every mushroom. Figure 2 shows such a mushroom, from a very heavily infested bed. In such beds the mites may



FIGURE 2.—Mushroom mites (*Tyrophagus lintneri*) on an immature mushroom from a heavily infested bed,  $\times$  about 12.

consume all the mycelium and attack the compost, eventually reducing it to a semiliquid mass of finely comminuted particles.

The mites, in feeding, use their chelicerae rapidly and alternately the food material being pulled into the mouth and swallowed. Mites have been seen to follow the mycelial threads, cutting them at intervals and destroying much more than they consume.

## CONFUSION OF MUSHROOM MITE INJURY WITH THAT FROM OTHER PESTS

Mite injury to the spawn in the beds at any stage is not characteristic, since it consists merely of the disappearance of the mycelium, as shown in figure 3, *A*, with an occasional attack on the compost. Furthermore, this injury is usually compounded to some extent by the attacks of any of several other mite or insect pests. The only way to be sure what pest is causing the damage is to examine samples of the compost from the beds under a strong magnifying glass. Probably the injury is due mainly to whatever insect or mite predominates in these samples.

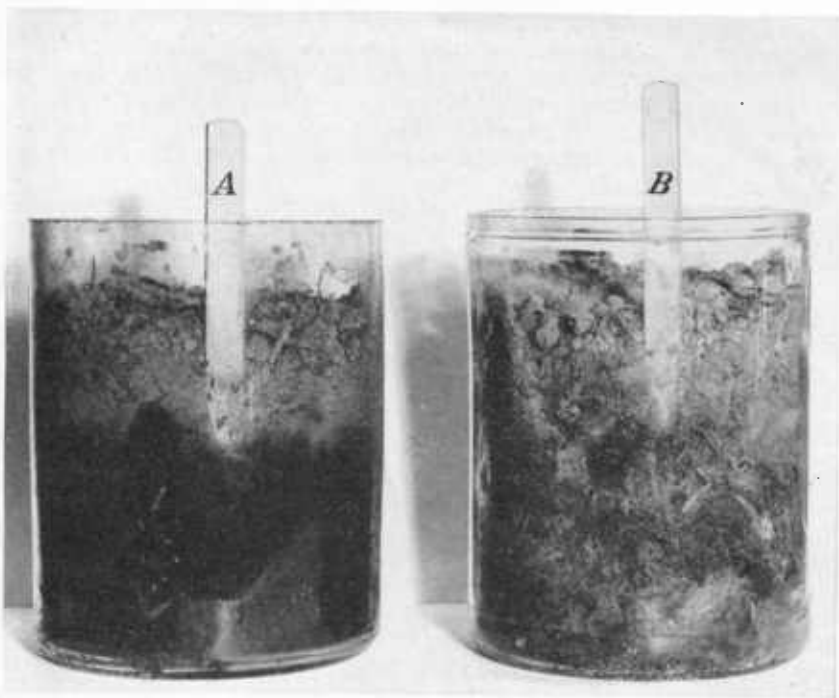


FIGURE 3.—*A*, Spawn attacked by the mushroom mite; *B*, normal spawn.

The injury to mushrooms (sporophores) by acarid mites, however, is rather characteristic, consisting, as has been stated, of irregular holes in the cap or stem, each with smaller dark, slimy pits within. Fly larvae usually eat small tunnels, and springtails cause many small irregular holes. Nematodes make irregular pits in the mushrooms, but these are shallow and extremely slimy throughout. In case any doubt exists, the grower should persist in the search until he actually finds the pest responsible for the trouble.

## SYSTEMATIC POSITION

The taxonomy and nomenclature of *Tyrophagus lintneri* (Osb.) and some related species of the family Acaridae were explained in 1942 by Ewing and Nesbitt (9). The synonymy of these mites has

been very confused, and that of some of them is still uncertain. The genus *Tyrophagus* and family Acaridae have formerly been known as *Tyroglyphus* and Tyroglyphidae, respectively.

### METHODS OF REARING AND OBSERVING

A number of types of cells were tried for rearing these mites. The usual type is that of Michael (18) and others, which consists of a glass ring cemented to a slide and covered with a cover glass held on with paraffin or petroleum jelly. Another type has a bottom of wax or plaster, dispensing with the slide but using a cover glass in the same fashion. These offer plenty of room for the mites and do not dry out readily, but these advantages are offset by the fact that they are open only on one side, that they are bulky and difficult to handle (a manifest disadvantage where hundreds of individuals must be handled and examined), and that the mites either eat the paraffin seal or become covered with the jelly. Hanging-drop slides have the disadvantage of becoming too wet with condensed moisture, frequently drowning the mites.

The most satisfactory type of cell was found to be one of paper held between two microscope slides. A heavy 3-ply drawing paper of the best quality is cut into pieces, each slightly smaller than a microscope slide (about  $\frac{7}{8}$  by  $2\frac{3}{4}$  inches). In the center of each of these pieces a hole about  $\frac{1}{4}$  inch in diameter is punched. It is important that the punch be one which cuts a hole with a clean edge, otherwise larvae are sometimes able to hide in the ragged edge of the hole. The paper should be of the best quality so that long and continued soaking will not cause it to come apart.

In preparing a cell the paper is soaked in water, pressed between two pieces of blotting paper to remove excess moisture, and placed on a microscope slide, preferably one of the thin "mending slides." For eggs and young mites a single thickness of paper is sufficient, but for adults two thicknesses are necessary with the holes in exact register. A small bit of food is placed in the cell, the mite or mites are lifted in on the point of a fine brush and put into the cell, another microscope slide is placed on top, and the whole is wound with several turns of heavy waxed thread or clipped together with small clips of spring brass. Slips of paper carrying numbers or other identification marks may be slipped beneath the thread or clips.

At first thin slices of fresh mushroom were used as food, but dried mushroom was found to be just as acceptable to the mites and far easier to keep on hand. The food material should be placed so that it touches the edge of the paper, where it soon becomes moist and soft and where the moisture content may be regulated. By regulating the amount of water in the paper the cell may be kept at the proper humidity and the food at the proper moisture content. Cells so prepared may be handled with a minimum of care, and observations may be made rapidly and easily at any time from either side, with either the low-power binocular or the compound microscope.

By wetting the paper the cells were kept as moist as was compatible with the safety of the mites. At times moisture condensed in the cells in such quantities as nearly to drown the mites therein, necessitating a change to a drier cell. In the absence of any method of measuring the humidity in such small spaces, it is presumed that the

cells were kept at as nearly a saturated humidity as possible. Observations in cultures, mushroom houses, and cheese storage rooms have led to the belief that variations in relative humidity, provided they are within reason, may not play as important a part in the life history of *Tyrophagus lintneri* as they do in that of some of the other Acaridae. At any rate, these mites are capable of withstanding relatively dry as well as relatively moist conditions.

Stock cultures of mites were maintained in quart milk bottles containing mushroom spawn or moldy or otherwise damaged grain.

Measurements of all stages of the mites were made without including the chelicerae, as they are capable of being either bent down or straightened out, altering the measurement considerably.

Observations were made at intervals, but the acts of oviposition, hatching, and molting usually took place at night, and were seen in only a few cases.

In case it became desirable to distinguish certain mites in a culture for a few hours, these individuals were fed on wax pencil such as is used for marking glass. They ate this material readily, and the colors of the wax in the intestine were distinguishable through the body wall for 24 hours or more.

## DESCRIPTION OF STAGES

### THE EGG

The eggs of *Tyrophagus lintneri* (fig. 4, *D*) are regularly elongate oval, clear shining white when first laid, and with a smooth shell. They are from 0.11 to 0.13 mm. in length, averaging 0.12 mm., and from 0.06 to 0.08 mm. in diameter, averaging 0.07 mm. After 2 days of incubation one end of the egg becomes hyaline. Just prior to the hatching of the egg, the shell shows irregular longitudinal markings, alternately lighter and darker.

### THE LARVA

The larva of *Tyrophagus lintneri* (fig. 4, *A*) has only six legs, the posterior pair not appearing until after the first molt. This first instar is a clear, semitransparent white, having a wet, sticky appearance. The bristles, or setae, are not so numerous as on the later stages, and are arranged as shown in the figure. The length of the larvae in the series measured ranged between 0.10 and 0.13 mm., and, as shown in table 1, averaged 0.116 mm. The series reared through to maturity and the records of sex kept show that size cannot be taken as an indication of sex in any of the immature stages.

TABLE 1.—Length of the mushroom mite (*Tyrophagus lintneri*) in various life-history stages

Stage	Average length of body of—		
	Male	Female	Both sexes
	<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>
Larva.....			0.116
Protonymph.....	0.181	0.191	.182
Deutonymph.....	.240	.246	.246
Adult before mating.....	.276	.332	.313
Adult after mating.....	.304	.372	.346

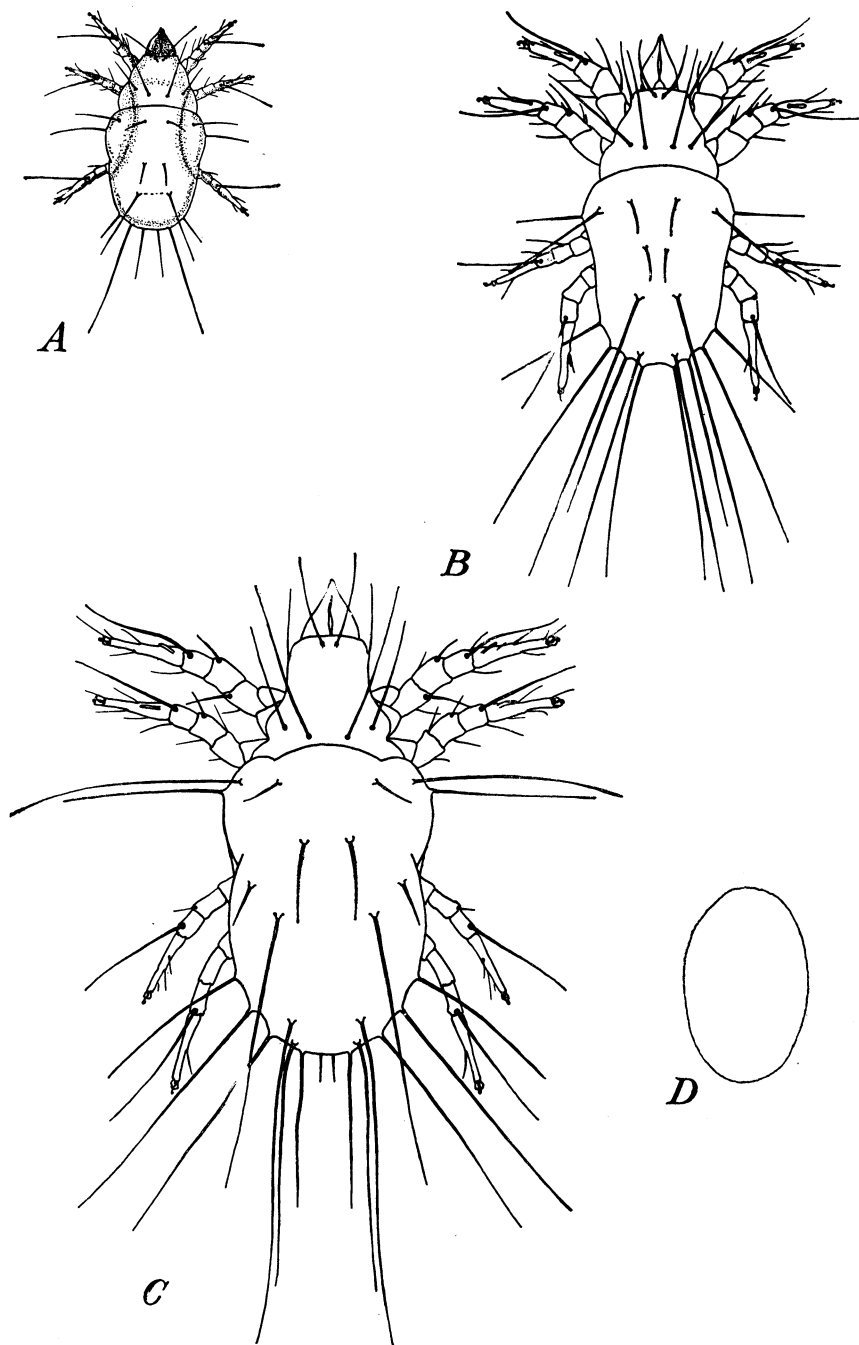


FIGURE 4.—Developmental stages of *Tyrophagus lintneri*: A, First instar (larva),  $\times 200$ ; B, third instar (deutonymph),  $\times 200$ ; C, adult,  $\times 160$ ; D, egg,  $\times 200$ .

## THE PROTONYPH

The nymph of the second stadium, or protonymph, is larger than the larva, measuring from 0.14 to 0.25 mm. in length, with an average of 0.182 mm. It is octopod, and the humeral angles of the body are usually conspicuous, giving the nymph a diamond-shaped appearance when viewed from above or below. It is nearly colorless at first, but soon becomes a light amber yellow. The body bristles are longer in proportion and more numerous than in the larva.

## THE HYPOPUS

Among the Acaridae there is a curious stage between the two nymphal stages, called the hypopus or hypopial stage. The hypopus is a very different creature from the octopod nymph from which it originated, being flattened, with a very hard, leathery integument, short, weak legs, and no mouthparts. Toward the posterior end of the ventral surface there is an area provided with several circular suckers. In some species of acarid mites the hypopus is rare or lacking, whereas in other species it is very common indeed. Not all individuals pass through this stage, even in species in which it is common, and the conditions governing its formation are not well understood. Hypopi are able to survive adverse conditions, such as dryness, for a much longer time than the adult mite, and this, coupled with the fact that they require no food, makes the stage well fitted for dissemination.

The hypopi attach themselves by means of legs and suckers to any moving object that comes within grasping distance, such as a fly, clothing of workers, or tools. Flies have been seen that were so covered with hypopi as to be unable to fly. Normally, however, the "free ride" terminates in another locality, when the hypopus drops off. If conditions there are favorable for its development the hypopus molts, becoming a deutonymph (third instar), which in turn becomes an adult.

Some species of adult acarid mites, such as *Histiostoma gracilipes* Banks, which also occurs in mushroom beds, are sluggish and soft-bodied, adapted to living in a semiliquid medium, and unable to withstand much desiccation. Such species are poorly equipped for making their way to new localities in the adult stage, and, as would be expected, hypopi are freely formed. *Tyrophagus lintneri*, on the other hand, is able to withstand quite a range of dryness and temperature in the adult stage and is rather agile and, on the whole, well adapted to making its way to a new environment. To this species the hypopial stage is less essential, and therefore rare, not having been observed by the author.<sup>5</sup>

Mites have been reared in quantity in cultures, and in some numbers in individual cells. Several strains have been maintained from time to time, yet in nearly 10 years no hypopi have appeared that could with certainty be referred to *Tyrophagus lintneri*. All hypopi reared proved to be those of other species, usually those of *Histiostoma*, which had somehow gotten into the cultures.

Acarologists for many years failed to connect the hypopi with the adult acarid mites, but described them as species of the genus *Hypopus*. After some time the work of Mégnin (16) and Michael (17) proved them to be an extra nymphal stage of the Acaridae.

<sup>5</sup> H. E. Ewing, in correspondence, states that he has identified the hypopi of this mite in cultures.

## THE DEUTONYMPH

The nymph of the third stadium, or deutonymph (fig. 4, *B*) differs from the protonymph in being somewhat larger (0.17 to 0.31 mm. in length, averaging 0.246 mm.) and in having the humeral angles of the body somewhat less conspicuous. It resembles the adult very closely in appearance, except that the sexual organs are not fully developed. It is slightly smaller, however, and the body bristles are shorter.

## THE ADULT

The adult mite (fig. 4, *C*) is semitransparent and usually a diffuse pinkish or yellowish, depending on the color of the food in the intestine. There is usually also a large, median brown or brownish spot, which seems to be the contents of the crop showing through the integument, and two smaller lateral spots marking the positions of the oil sacs. The integument is smooth and polished and without markings. The dorsum is smoothly convex or somewhat flattened as viewed from the side, depending on the quantity of material in the alimentary canal. As seen from above the abdomen is rounded posteriorly, strongly indented at the sides at about the anterior third, and truncate anteriorly. There is usually a rather prominent longitudinal sulcus at each side just within the humeral angles, but as these sulci seem to be due to the attachment of interior muscles their prominence varies. The cephalothorax is nearly cone-shaped, the base narrower than the base of the abdomen and separated from it by a distinct groove. The rostrum is rather small, and the mandibles (chelicerae) are toothed, as shown in figure 5, *C*. There is some variation in the length of the teeth and in the robustness of the chelae, but the arrangement of the teeth seems to vary little. The arrangement of the body hairs is shown in figures 4, *C*, and 5, *B*. Although not shown in the figure, all the hairs of the body and most of those of the legs are minutely bipectinate, as shown in 5, *A*. The legs of *Tyrophagus lintneri* are rather long and slender, the tarsi equal to or longer than the two preceding joints together.

Although the pectinations of the bristles of these mites are minute, they are visible even with the low-power binocular in living specimens or dry mounts. In mounted specimens, however, they are very difficult to see. It is necessary to have the focus and light exactly right in order to distinguish them. It was thought at first that they were extremely fragile and folded in upon the parent hair when placed in the mounting medium, but this seems not to be the case. Seemingly they are extremely thin, and clear very rapidly, becoming very difficult to distinguish. Since most acarologists have worked with mounted material it seems possible that this character might have been overlooked in some cases, even when present.

## SEXUAL CHARACTERS

The sexes can be distinguished under the low-power binocular, although not with any great certainty. The male is usually smaller and less robust than the female, minor differences in the shape of the body can be distinguished, and with just the proper light the minute depressions of the copulatory suckers may be distinguished. The

rearing cells, however, may be placed under the compound microscope, and the sex of mites kept therein determined with little or no difficulty.

*Male.*—The penis of the male is situated between the fourth pair of legs, and, with its chitinous sclerites, appears as shown in figure 6, *A*.

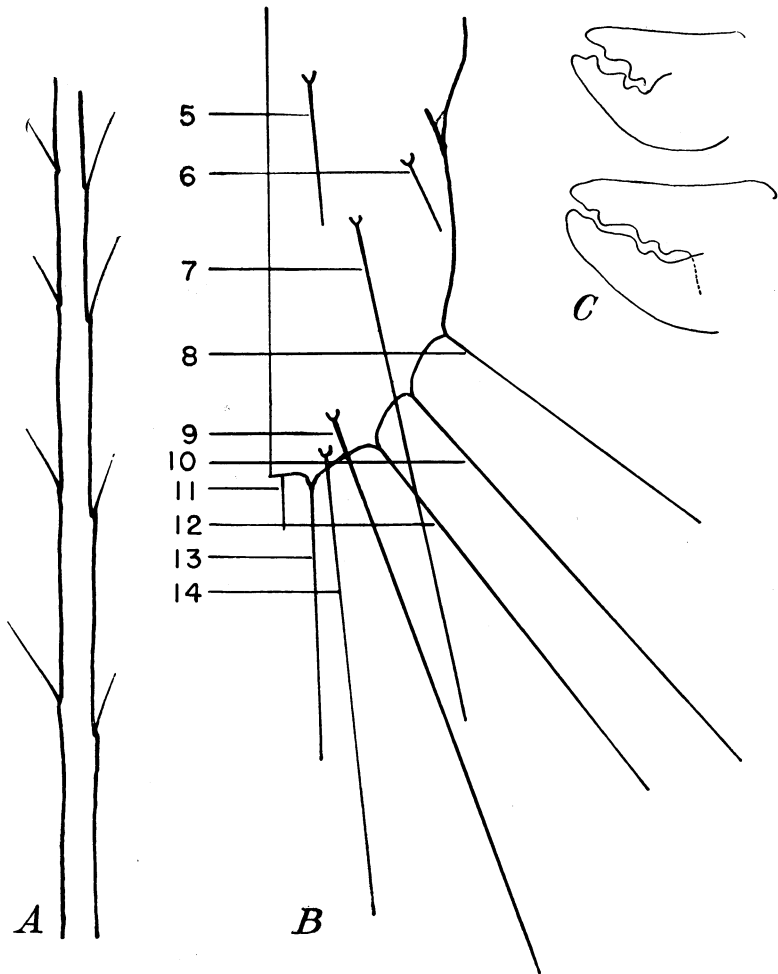


FIGURE 5.—Details of anatomy of *Tyrophagus lintneri*: *A*, Part of posterior body bristle, showing pectinations; *B*, diagram of posterior half of body, showing arrangement of hairs; *C*, the chelicerae, showing the arrangement of teeth. The numbering of the hairs in *B* corresponds with that by Jary and Stapley (13) for another species.

The anal, or copulatory, suckers are situated one on each side of the anus at its posterior end (fig. 6, *B*).

*Female.*—The vulva of the female is situated between the third and fourth pairs of legs (fig. 6, *C*). No anal suckers are present. In a lateral view the raised edges of the copulatory pore may sometimes be distinguished on the postero-dorsal surface, above the anus.

## DEVELOPMENTAL PERIOD

## DURATION

The duration of the different stages in the development of the mushroom mite was determined at 76.5°, 65°, and 55° F., which represent temperatures that are usually employed during the successive periods in the culture of mushrooms, as will be discussed under the section Life History in Mushroom Houses (p. 16). The two lower temperatures were maintained in temperature cabinets and were constant within plus or minus three-fourths of a degree. The higher temperature was that of the laboratory room and varied between 72° and 80° F. but was between 75° and 78° more than 90 percent of the time.

As shown in table 2, the duration of the developmental periods of individual mites differed greatly, particularly when these were reared at 55° F. Temperature had considerable effect on development, the average durations at 76.5°, 65°, and 55° F. being 12, 19, and 54 days, respectively. The average durations of the four stages were near the

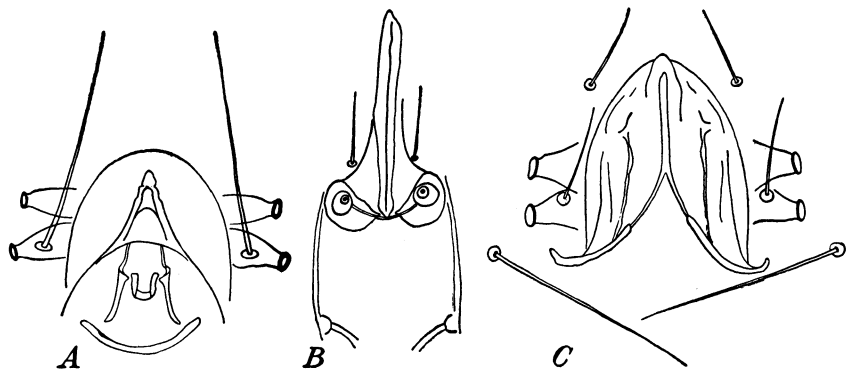


FIGURE 6.—Details of genitalia of *Tyrophagus lintneri*: A, Penis and accompanying sclerites of male; B, anal suckers of male; C, vulva of female.

same length, but the larval and protonymphal stages were a little shorter than the others. The temperature had about the same influence on all four stages. Records of a number of mites reared at the higher temperature show that the females tend to develop a little faster than the males.

## HATCHING

Prior to the hatching of the egg, the shell shows irregular longitudinal markings, alternately lighter and darker, resembling in this respect a miniature "rattlesnake" watermelon. The movements of the legs and chelicerae of the larva may be detected through the shell. The chelicerae work in a scraping motion against the side of the shell, and the legs move vigorously at intervals. With frequent pauses for rest it requires certainly 2 and probably 4 or more hours for the larva to break the shell. The actual hatching occupies only 2 or 3 minutes. After the eggshell has been ruptured by the chelicerae it is further split by movements of the legs, until the rupture involves progressively one side, one end, and usually most of the other side of the egg. The end that is split may be at either the posterior or anterior end of the larva.

TABLE 2.—*Duration of stages in the life history of the mushroom mite (Tyrophagus lintneri) at different temperatures, Beltsville, Md., 1936-40*

Stages in life history	Temperature	Individuals observed	Duration		
			Maximum	Minimum	Average
	°F.	Number	Days	Days	Days
Egg stage.....	55	239	30	7	15.1
	65	69	14	3	7.1
	76.5	112	7	2	3.9
Larval stage.....	55	232	46	5	12.0
	65	69	6	2	4.3
	76.5	98	5	2	3.0
Protonymphal stage.....	55	201	36	3	9.4
	65	68	5	2	3.3
	76.5	86	5	1	2.5
Deutonymphal stage.....	55	100	94	4	18.2
	65	67	28	3	4.8
	76.5	80	9	1	3.2
Total period of development.....	55	99	138	33	54.0
	65	67	44	15	19.3
	76.5	83	18	10	12.3
Adult life <sup>1</sup> .....	55	29	112	3	35.0
	65	65	235	10	66.6
	76.5	62	209	2	53.0
Total life <sup>1</sup> .....	55	36	184	47	84.7
	65	65	253	29	85.9
	76.5	66	219	15	64.5

<sup>1</sup> Of individuals reared in confinement only.

In one of the few actual observations made upon hatching the progress was as follows: Movements of the legs were first noted at 9:57 a. m. At 10:12 the chelicerae were biting at intervals at the shell. They showed deep brown at this time. At 10:25 the larva was very active, but took frequent rest periods. At 12:34 the eggshell was finally cut through by the chelicerae and the rupture continued by the kicking of the legs until the shell was split back one side and around the end and for one-third of the opposite side. At 12:37 p. m. the larva backed out and was clear of the shell and moving off.

There seems to be little natural mortality during incubation. Of 1,292 eggs kept for observation on this point only 8, or 0.6 percent, failed to hatch.

#### THE LARVAL STAGE

The larva may be found in mushroom houses in the spawn or on the mushrooms, in association with the other stages of the mite, and feeding in the same manner. It begins feeding almost immediately after hatching.

Prior to the first molt the larva becomes quiet, and the body becomes pear shaped and tightly distended, the rostrum extending horizontally forward, and the legs being stiffly extended. After a period of from 2 hours to more than 2 days the larval skin splits down the back, and the nymph works its way out backward and walks away. The quiescent, tumid condition precedes every subsequent molt.

#### THE NYMPHAL STAGES

Both the protonymph and the deutonymph have eight legs and therefore resemble the adult mite more than does the larva. The nymphs begin to feed soon after the molts, and their behavior and feeding habits are the same as those of the adult mite, except for sexual activity of the latter.

In one case observed there was an extra molt, though no hypopus was formed, and there was no great difference in appearance among the nymphal stages.

## ADULT LIFE

## EMERGENCE

The final molt leading to the mature stage is much the same as those preceding. The nymph becomes quiescent and tumid after voiding the contents of the intestine. After a resting period ranging from several hours to 2 or 3 days the nymphal skin splits down the midline of the back, and the adult works its way backward out of the old skin. For a time the mite is white or colorless, but within from 2 to several hours the integument becomes yellowish. The mite resumes feeding in a short time after the molt.

## TROPISMS

Though mushroom mites have no eyes they are sensitive to light and will eventually place themselves in such a way as to avoid it.

The majority of individuals are negatively geotropic, but they usually wander about considerably before settling.

Mites will leave situations where conditions are too dry to suit them, but many times the reaction is to burrow more deeply into the spawn rather than to leave it altogether in the search for moisture.

## LONGEVITY

The length of adult life of mites reared in cells and closely observed during development was shown in table 2 to range from 3 to 112 days at 55° F., from 10 to 235 days at 65°, and from 2 to 209 days at 76.5°. The averages at the 3 temperatures were 35, 67, and 53 days respectively, indicating that 65° is the more favorable temperature. It is believed, however, owing to the fact that the mites were reared in confinement, that the above figures are too low to represent the normal periods in nature.

A series of mites taken from a stock culture and placed in cells at 55° F. immediately after the third molt lived as adults more than 5 times as long as did mites that had been reared in cells. One mite of this series lived 419 days and another 401 days. The average life was 197 days. Data on the effect of confinement are given in table 3. There seemed to be no great difference in the length of adult life of the males and females.

TABLE 3.—Length of adult life of mushroom mites at 55° F. as influenced by isolation in cells for observation during development

MATED INDIVIDUALS					
Treatment during development	Sex	Individuals observed	Adult life		
			Maximum	Minimum	Average
		Number	Days	Days	Days
Isolated in cells.....	Female.....	10	67	16	29
Not isolated.....	do.....	8	221	98	158
Isolated in cells.....	Male.....	10	90	3	25
Not isolated.....	do.....	5	401	93	222
UNMATED INDIVIDUALS					
Isolated in cells.....	Both.....	9	112	10	53
Not isolated.....	do.....	7	419	24	224

## MATING

The sex ratio as determined from 532 mites was 58 percent females, and this ratio did not seem to be materially affected by difference in temperature.

Female mites are capable of mating almost immediately after the final molt if males are present in numbers, as in laboratory cultures. Under mushroom-house conditions, if the infestation of mites is not heavy it may be several days before the individuals of the sexes encounter one another. The act of copulation requires normally from about 30 minutes to 2 hours or more, and females sometimes oviposit very shortly thereafter. In one case in the laboratory a female emerged, mated, and laid the first egg, all within 6 hours. As a general rule, however, the preoviposition period occupies 2 or more days.

Females of the mushroom mite do not normally oviposit before copulation. Only 1 egg was so laid by 63 unmated females reared and kept for longevity records, and this egg was infertile. The female that laid the egg had been in the adult stage for about a month. The mites copulate a number of times during their adult life. It has been repeatedly observed that females that had mated once and had been kept in isolation thereafter usually oviposited less and less frequently after a few days, ceasing altogether after about 25 days. If a male was then placed in the cell, copulation took place almost at once, and oviposition was resumed at about the normal rate after about 24 hours. Similarly, if the male of an old pair dies and no other male is put into the cell, oviposition is retarded and finally ceases long before the normal time; but if a male is introduced, oviposition is resumed. From this it appears that frequent copulation is essential to the maintenance of a normal oviposition rate. All eggs, even the last ones laid after the death or removal of the male, are fertile, from which it appears that these mites normally lay nothing but fertile eggs, and do not, as do many mites and insects, continue to oviposit in the absence of sperm.

As a matter of curiosity four females were mated 26 to 57 days after the third molt to determine what the ultimate effect on oviposition would be. These adults lived nearly twice as long as others mated soon after completing the third molt. The average length of life after mating was 33 days and 28 days for the two groups, respectively, and the oviposition period 28 and 27 days, respectively. The rate of oviposition as well as the total number of eggs laid was slightly decreased by delayed mating. It seems that if mating is not too long deferred, females are able to lay almost as many eggs as those mated early, and that the longer preoviposition period is merely that much added to their total length of life.

## OVIPOSITION

In the mushroom houses eggs may be laid at any time during the 24 hours, since the houses are dark. In the laboratory mites kept in a place exposed to daylight oviposit mostly at night, but mites kept in a dark place oviposit at any time.

Eggs are laid singly and deposited at random wherever the female happens to be. In the mushroom houses this may be in the spawn, on mushrooms, on the casing soil, or on the bed boards or supports.

The eggs are not fastened in place in any way but are merely dropped. The act of oviposition has not been observed, but must occupy only a very short time for each egg.

As a rule, a female will oviposit infrequently at first, gradually increasing the rate of oviposition until a peak is reached, when the rate gradually slows until the oviposition period is terminated, usually some hours or days before death. The time necessary to reach the period of maximum egg production after the first egg is laid varies so greatly with individuals that an average means little. At 55° F. it is about 36 days, at 65° about 25 days, and at 75°–78° about 6 days.

#### NUMBER OF EGGS DEPOSITED

The female mites reared and held in cells at a temperature of 65° F. laid from 267 to 655 eggs, an average of 454 during adult life, or about 6.4 eggs per day. As shown in table 4, mites reared at 76.5° averaged almost as many eggs (312), but those reared at 55° produced an average of only 16. Of 10 females reared at 55° and mated, 5 did not oviposit at all, indicating that this temperature is close to that at which oviposition would cease entirely.

TABLE 4.—*Eggs laid by the mushroom mite as influenced by the history of the adults and by temperature*

BY FEMALES THAT DEVELOPED IN REARING CELLS					
Temperature (° F.)	Females observed	Average adult life	Eggs produced		
			Maximum	Minimum	Average
	Number	Days	Number	Number	Number
55.....	10	29	58	0	16
65.....	13	71	655	267	454
76.5.....	20	44	712	8	312
BY FEMALES THAT DEVELOPED IN STOCK CULTURE					
55.....	8	158	110	0	56

The strain of mites used in the foregoing studies was taken from mushroom houses which are customarily kept at 55° to 60° F., or higher, depending on weather conditions and on whether market conditions demand a quick crop. Another strain of mites kept for comparison, which was obtained from a cold room in which cheese was ripened, was conditioned about 10 degrees lower than the mushroom-house strain, and was quite active at 55°.

#### LIFE HISTORY IN MUSHROOM HOUSES

All conditions in mushroom houses being artificial, true seasonal variation in abundance of mites cannot be said to exist except as the mites become increasingly more abundant all through the season during which mushrooms are grown.

The temperature at which the houses are held during the various stages of culture may have a great influence on the rate of development. In general the procedure in growing mushrooms is as follows:

After the mushroom house has been filled, the compost in the beds goes through a secondary fermentation, raising the temperature of the house to 120°–140° F.<sup>6</sup> Growers usually endeavor to maintain the temperature at or above 130° for a time, and fumigate the house when the temperature begins to drop. The temperature is then allowed to drop slowly.

When the temperature of the beds has dropped to 80° F., spawn is introduced, and the temperature is allowed to drop to around 72° for the first 2 weeks or so of the spawn run, then slowly dropped again to around 60° just before casing. Casing consists in covering the surface of the beds with  $\frac{3}{4}$  to 1 inch of good loam. The beds are held at about 60° until the first small mushrooms appear, when they are cooled to the picking temperature, which ranges from 52° to 60°, or even higher, depending upon whether a slow or fast crop is desired. Most growers prefer 55° or a trifle higher. This is especially true of the growers who raise only one crop of mushrooms per year. If the temperature within the house is allowed to rise above 70° for more than a few days after the beds come into production the crop is ruined.

There are, then, three temperatures from the beginning of the crop, (1) the temperature during the spawn run (72°–75° F.), (2) the temperature after casing (60°), and (3) that during the picking period (55°–60° or higher). The first period lasts from 10 days to 2 weeks or more, the second from 2 to 3 weeks, and the third until the crop is finished.

If adult mites are introduced into a mushroom house at the time of spawning temperature (80° F.), the first eggs laid by these will develop into adults in less than the 2-week period of the spawn run (see table 2), and these will probably be ovipositing before the temperature is dropped for casing. Meanwhile the original mites will continue to lay eggs. These eggs, together with the first ones laid by the second generation of mites, will probably require about 5 weeks as the temperature drops from 72° to 60° and later to 55° within about 3 weeks. Later generations will require an average of about 2 months, allowing several days preoviposition period. As shown in table 3, the adult females developing under more or less normal conditions will survive an average of more than 5 months at 55° and some will survive 7 months. Adults belonging to three or more generations will therefore be depositing eggs at the same time. In the case of a grower who fills the house but once a year and keeps the temperature low, the picking period may last from 4 to 6 months, and during this time there may be two or three additional incomplete generations, making a total of four or five.

Some growers keep the temperature at 60° to 65° F. in order to shorten the picking period to about 3 months so that a second crop can be started. In such cases the mites will develop to maturity almost three times as fast and lay about eight times as many eggs as at the lower temperatures. Therefore, in a much shorter period the population of mites will become much larger and cause more damage.

Mushroom mites normally move about almost constantly; and since the eggs are dropped wherever the female happens to be, the progress

<sup>6</sup> This period is usually spoken of by the growers as the "heat." During the heat the compost "sweats out," i. e., loses its excess moisture and undergoes a curing. The point of maximum heat, just before the temperature begins to drop, is known as the "peak heat."

of an infestation, once established, is fairly even throughout the house.

In the wild state these mites undoubtedly follow the same rule as do other mites and insects, becoming less abundant in winter. In the mushroom houses an infestation, once begun, becomes more noticeable as the end of the crop season approaches. From year to year, however, there is a marked variation in their numbers, probably because of better sanitation in some years than in others.

## SOURCES OF INFESTATION

Since *Tyrophagus lintneri* is capable of attacking cereals, and, as well, hay, straw, and other organic materials, it is probable that the mites are introduced into the mushroom houses in small numbers with compost from infested stables. Jary and Stapley (13), writing of *T. longior*, record such a case in England. To date *T. lintneri* has not been recovered from samples of compost, although *Rhizoglyphus phylloxerae* Riley, a closely related species, is present in abundance in the relatively cool outer layers of some compost heaps. The ubiquitous nature of these mites makes it probable that a few are present in and about the mushroom houses at all times, as is probably the case with *Glyciphagus domesticus* De Geer in dwelling houses (10). In one case noted the initial infestation, without much doubt, was attributable to infested cheese brought into the house in the lunch of one of the workmen and discarded there when found to contain mites. Many infestations are undoubtedly due to workers carrying the mites from house to house on their clothing. Rubbish lying about the mushroom houses may harbor mites which are able to crawl out and infest the houses. Other acarid mites have been reported as being carried about in the adult stage by bees, flies, and other insects, and it is reasonable to suppose that *T. lintneri* might also be thus carried about.

## NATURAL CONTROL

### CLIMATIC CONDITIONS

Under mushroom-house conditions climatic factors play little or no part in control of the mushroom mites except insofar as these partially control the condition of the manure when it is placed in the houses, and therefore the temperature of the "heat." It has long been recommended that spent mushroom compost be hauled to some distance from the houses and spread thinly over the soil in order that the elements might destroy as many as possible of the pests present. If the soil is sufficiently dry and the temperature high enough to heat and dry out the compost this procedure will undoubtedly kill many mites, but if drying out is too long delayed many of them will work down into the soil. Ostrovsky (22) has shown that *Tyroglyphus putrescentiae* Schr., a related species, would not remain in soil with only 20 percent of moisture, but could survive at 40 percent, and that soil at 70 percent of moisture contained most mites. In grain spawn, mites were found to prefer a 69.93-percent moisture, dry-weight basis.

If compost is removed from the mushroom houses in the winter and spread over the soil, freezing will kill great numbers of the mites. Iljinskaya (11) has found that *Tyroglyphus putrescentiae* and

*T. farinae* were able to survive the winter in Russia in fall-sown grain, going into a torpid state, but becoming active again in the spring. These mites, however, were under the surface of the soil, where they were partially protected. Experiments have shown that if spent compost is exposed to freezing, the strain of mites from the mushroom houses, being more or less conditioned to a temperature of 55° F. or above, will very shortly become motionless and remain so. If kept frozen for from 5 to 7 days (temperature about 30° or below) very few of the mites recover. This is comparable to spreading spent compost on frozen ground or on the snow.

Throwing open the houses and allowing the mushroom beds to freeze solid for a week or more during severe weather is said by growers who have tried it to kill a great many pests and to invigorate the spawn to some extent.

During the time that the mushroom houses are empty and open, after they have been cleaned, mites may be at least partly controlled by keeping the houses as dry as possible. According to Oboussier (19) even 75 percent relative humidity is unfavorable to tyroglyphid mites and most of them die within 24 hours at 54 percent humidity.

#### NATURAL ENEMIES

On the whole, predators do not normally play an important part in control of mites in mushroom houses. Mites of the family Gamasidae (Parasitidae) are frequently abundant in compost piles and in mushroom houses, and have repeatedly been observed to attack mites and springtails. In Russia, mites of the genus *Cheyletus* have been noted as attacking other mites, probably the species of *Tyroglyphus* which were present in stored grain (25). In England, Chorley (2) mentioned an unnamed centipede preying upon *Tyroglyphus mycophagus* Megn. The staphylinid beetle *Atheta virginica* Brnh. was observed by Thomas (24) feeding upon mites of the genus *Tarsonemus* and they would probably attack *Tyrophagus* also. Another beetle, *Acritus* sp., was seen attacking mites at Arlington Farm, Va. (3).

#### CONTROL BY SANITATION

The common acarid mites are most difficult to control, and represent probably the most stubborn pests of cultivated mushrooms. *Tyrophagus lintneri*, in particular, is capable of surviving a wide range of temperature, humidity, and food conditions, and is difficult to kill by ordinary fumigants. In attempts at the eradication of pests the mushroom grower is hampered by the fact that most insecticides have some fungicidal effect also, and must be used with caution or not at all. On the other hand, as Lambert (14) remarks: "... like the greenhouse man, he finds it helpful to be able to control his universe [the mushroom house] in programs of eradication and exclusion and quite refreshing to be able to do something about the weather."

It is therefore easier to prevent the development of an infestation than it is to control one after it is established. Proper hygiene is by far the most important method of mite control. It is noticeable that in mushroom houses where sanitary measures have been practiced as

a routine for several years, mites have been absent or so few as to be unimportant.

Sanitation should begin in the stables where the manure for mushroom production is obtained, as this will aid in mite control. Where litter and manure are allowed to accumulate, a mite population may build up rapidly. If manure from such a stable is not carefully composted and heated, enough mites may survive to initiate an infestation in the beds after they are spawned. If the manure is to be stored for any great length of time it is especially important that it be as free from mites as possible, as certain layers of storage heaps offer ideal conditions for mite development, and if the mites are able to increase greatly in numbers they are liable to infest the whole premises.

Immediately after the compost is put into the houses the composting floor should be cleaned, all manure and rubbish removed, and the surface well scraped. A week or 10 days before the receipt of new manure the floor should be drenched with a solution of 1 gallon of formaldehyde to 50 gallons of water or with boiled lime-sulfur at 1 gallon to 10 gallons of water. The latter is the more effective of the two against mites. The floor should be allowed to dry and air for 2 or 3 days before the manure is placed upon it.

It has been shown (14, 15) that in the average mushroom compost heap there are four areas representing four different sets of conditions of temperature, moisture, and aeration. The outer "shell" of from 2 to 6 inches is relatively cool and dry whereas the lower center is wet, but relatively cool, and contains little or no oxygen. The other two areas, comprising over half the heap, have temperatures of over 130° F.—too hot for insects or mites to survive. It is important, then, that the manure in the outer layer and the lower center of the heap be thrown to the inside of the heap at each turning, not only to hasten and improve composting, but to insure the death of any pests that may be present.

After removal of compost of the preceding crop the bed boards should be washed or scraped and brushed clean, and all dirt and rubbish should be removed from the house. About 2 weeks before filling, the boards and the interior of the house should be sprayed with boiled lime-sulfur, 1 gallon to 10 gallons of water. This spraying eliminates any insects, mites, or diseases that might have survived in the house from the preceding crop.

Once begun, the filling of a mushroom house should be completed rapidly, so that as little as possible of the latent heat of the compost be lost. After the house is filled and the doors tightly closed the process of "sweating out" begins. Recent experiments have shown that this is possibly the most important part of the ordinary procedure of mushroom growing. During the secondary fermentation of the compost the temperature within the mushroom house rises markedly, and an attempt is made to maintain this temperature above 130° F. but below 140° for 7 to 10 days, not only to render the compost more favorable for mushroom growing, but to kill any pests that might have survived the composting or been introduced into the compost after the last turning.

Electric fans are customarily run in the house during the heating period to distribute the heat more evenly. If these are placed in the top of the house so that the air will be driven downward the blast of

warm air will raise the temperature of the floor a few degrees (this is important, as the floor is usually comparatively cool—not over 113° F. in any house tested to date). This position of the fans will keep them out of the way and during fumigation with hydrocyanic acid gas the operation of the fans will partially prevent the tendency of this gas to leave the floor. The fans should be removed from the house, however, during fumigation with sulfur dioxide, as this gas corrodes metals.

It is customary to fumigate the house when "peak heat" has been reached, i. e., when the temperature has reached its highest point and begins to drop. If, however, the house is so constructed that it must be opened to prevent overheating and consequent fire fanging of the compost, fumigation is done before the temperature exceeds 140° F.

Spent compost should be hauled to a place some distance from the mushroom houses for disposal (see p. 18) and should never be spread on land from which it is intended to take casing soil for subsequent crops. Although few flies survive in heaps of spent compost, mites and springtails have been found in some numbers in piles left adjacent to newly filled houses. Heaps of spent compost harbor germs and spores of mushroom diseases also.

The floors of mushroom houses should be kept clean at all times in order to afford shelter to as few mites as possible. Most modern houses have floors of concrete, which are much more easily kept clean than are dirt floors. Old manure, rubbish, or scraps of lumber should never be allowed to lie about the mushroom houses. Such material, especially in damp spots, offers the best places of refuge to mites and springtails, and may lead to the infestation of an adjacent house.

All weeds and accumulated leaves and trash should be removed for some distance around buildings, and all butts, discarded mushrooms, and other such refuse should be placed in a pit and covered with lime or oil—not merely dumped outside the houses where the pests may breed undisturbed.

## CONTROL BY CHEMICAL TREATMENTS

Studies on chemical treatments were begun with the knowledge that the mushroom mite and related species were difficult to kill. Sulfur fumigation for 24 hours, carbon disulfide, and turpentine had been tried to no avail. Mushroom mites have survived immersion in 10-percent potassium hydroxide for 80 minutes and in 95-percent alcohol for 25 minutes. Eales (8) records having kept *Tyroglyphus longior* in 5-percent formalin for over a week, at the end of which time many were still alive. Specimens of this species have passed through the human alimentary tract alive. Odagaki (20) says that some individuals of *Rhizoglyphus echinopus* F. and R., a related species, survived 149° F. for 1 hour. Jarvis (12) records that a fumigation with 24 ounces of cyanide (presumably sodium cyanide or potassium cyanide) per 1,000 cubic feet in a household failed to kill all individuals of *T. longior*, but when repeated with 32 ounces per 1,000 cubic feet no living mites could be found. The owner of the house later reported, however that a few were still present.

A large number of insecticides have been tried as fumigants, drenches, and dusts, in attempts to control mites in various situations.

## FUMIGATION AT PEAK HEAT

The theory in fumigation at peak heat is that pests that have survived the heat up to that time will have been driven out of the compost to some place where they can be reached and killed by the fumigant. The fumigants are also more effective at high temperatures. Either hydrocyanic-acid gas or sulfur dioxide is used.

Hydrocyanic acid gas may be generated in several ways, but the best, all things considered, is the pot method using not less than 8 ounces of sodium cyanide, 12 fluid ounces of sulfuric acid (66° Baumé), and 16 fluid ounces of water per 1,000 cubic feet (4). In experiments with cyanide fumigation under mushroom-house conditions it was found (4) that mites in a fumigation chamber brought from 75° or 80° to 100° F. (about the temperature on the floor of mushroom houses during the heat) in from 6 to 8 hours, held at 100° for 7 to 9 hours, and fumigated with hydrocyanic acid gas, were killed by a concentration reaching 3.6 mg. per liter, with a mean of 1.67 mg., and requiring 44 minutes to drop to 0.4 mg. per liter.

Sulfur dioxide gas is generated by burning a good grade of flowers of sulfur in any one of several different ways (5, 6, and 7). In sulfur fumigation it was found (7) that mites were killed in the fumigation chamber at 120° F. and 90 percent relative humidity by a concentration of about 6 mg. per liter, with a mean of about 3.8 mg., and requiring about 65 minutes to drop to 1.5 mg. per liter. Under the conditions found in mushroom houses between fillings (70°–80° and 80 to 90 percent relative humidity), concentrations of over 10 mg. per liter were necessary to obtain control of mites.

In experiments in mushroom houses at peak heat it was found very difficult to burn sulfur fast enough to obtain a 100-percent lethal concentration because of the rapid absorption of the gas by the moisture within the house. In fumigation with hydrocyanic acid gas the absorption of the gas is about as rapid as with sulfur fumigation but a large volume of the gas may be generated faster, resulting in high peak concentrations.

## FUMIGANTS TESTED

The more important of the fumigants tried were as follows:

Ammonia gas.	Methyl salicylate.
Carbon disulfide.	Naphthalene.
Carbon tetrachloride.	Nicotine, either burned as a smudge
Chloropicrin.	or boiled off.
Ethylene dichloride.	Orthodichlorobenzene.
Ethylene dioxide.	Paradichlorobenzene.
Formalin.	Pyridine.
Hexachloroethane.	Sulfur dioxide.
Hydrocyanic acid gas.	Tetrahydronaphthalene.
Methyl bromide.	Trichloroethylene.

Of these fumigants hydrocyanic acid gas is the one most used in mushroom houses. It will injure mushrooms if used in dosages sufficient to kill mites and is therefore used before spawn is introduced and while the house is at peak heat. Sulfur dioxide is also effective at this time, but it likewise cannot be used when mushrooms are present. Fumigation at peak heat with these two materials was discussed in the foregoing section.

Nicotine is used as a smudge to some extent, but it kills few mites, and it results in the absorption of considerable quantities of nicotine by the mushrooms.

Paradichlorobenzene is sometimes used for mite control. Caesar (1) recommends  $1\frac{1}{2}$  to 2 pounds per 400 square feet of bed space, sprinkled over the well-dried beds, the house to be tightly closed for 48 hours and this treatment to be repeated after 10 days. Spreading muslin over the infested portions of the beds, broadcasting the material over this, and covering the whole with newspapers for several days has also been recommended. Only a few mites were killed and mushrooms were damaged when exposed for 48 hours to 1 pound of paradichlorobenzene per 1,000 cubic feet of air space. The material was evaporated by spreading a shallow layer in a tray before an electric fan. Spawn was apparently injured, also, as the next flush of mushrooms was a week or more late in appearing.

Read (23) notes that mites were controlled in spawned, uncased mushroom beds by using naphthalene at the rate of 4 ounces per 1,000 cubic feet of air space, no injury to the spawn resulting. He recommends that it be scattered in the alleyways between flushes. Pyridine has given excellent results in the laboratory, but its odor is extremely objectionable and lasting in mushroom houses. Methyl bromide must be used at the rate of 3 pounds per 1,000 cubic feet of air space to control mites, and this dosage damages the spawn badly. Formalin is of little value against mites and kills the mushrooms. Of the other fumigants listed, some are too expensive or too dangerous to use, others damage the mushrooms and spawn, and a few have not been in use enough to be of certain value. Fumigants, as a rule, do not penetrate into the mushroom beds far enough to kill mites within the compost.

#### INSECTICIDAL DUSTS AND DRENCHES

The following materials were tested either as sprays or drenches, or as dusts for the control of mushroom mites:

Ammonia solution.	Nicotine (free).
Aniline.	Nicotine bentonite.
Borax.	Nicotine peat.
Carbolic acid.	Nicotine sulfate solution and dusts.
Carbon disulfide, pure, in emulsions, and mixed with naphthalene.	Oils, oil emulsions, and oil-based insecticides.
Caustic potash or soda.	Phenothiazine.
Chloral hydrate.	Phenoxathiin.
Chloride of lime.	1-Phenylazo-2-naphthylamine.
Creosote.	Phthalic glyceryl alkyl resin.
Cresol (sheep dip).	Pyrethrum extract in dusts and in drenches.
Derris, water extracts and dusts.	Pyrethrum powder.
Dichloroethyl ether.	Quassia.
Dinitro-o-cyclohexyl phenol.	Salt and salt solutions.
1, 4-Dinitrosopiperazine.	Soap solution.
Formalin.	Sulfonated Lorol.
Gasoline.	Sulfur.
Hellebore.	Thiocyanate. <sup>7</sup>
Kerosene.	Tobacco powder.
Male fern extract.	Turpentine.
Methyl alcohol.	
Methyl salicylate.	

<sup>7</sup> A proprietary preparation of an oily nature containing an organic thiocyanate, the composition of which is not known.

As controls for mites in mushroom houses, most of these materials may be eliminated at once. Although oils of various types have been used successfully they are to be avoided, as continued use of oils or oil-base insecticides eventually leads to trouble in the form of deformed and cracked mushrooms. This applies to the thiocyanate preparation as well as to the commercial fly sprays. Derris dusts and extracts injure the spawn, as does carbon disulfide in any form or combination. The latter material is unsafe to use because of the fire and explosion hazard involved. Of the remainder, carbolic acid, creosote, cresol, and formaldehyde kill the spawn; some, such as aniline, are too poisonous to be used safely by the average grower; and others, such as hellebore, are of little or no value against mites. The yield of mushrooms was reduced by the use of phenoxathiin, extract of thundergod vine, chloral hydrate, male fern extract, 1-phenylazo-2-naphthylamine, and the two dinitro compounds listed. Of the various materials tested to date, only nicotine, pyrethrum, methyl salicylate, and dichloroethyl ether have given good results.

The use of nicotine, as tobacco powder (1 percent of nicotine), mixed with the compost at the rate of 6 to 10 ounces per bushel before it is put in the house, has given a definite increase in yield, although in the laboratory mites feed freely on such compost and on that which has been mixed with nicotine bentonite or nicotine peat. Nicotine preparations applied as dusts are of little value against mites. Nicotine sulfate, 1 part of the 40-percent strength to 10 or 20 parts of water, has been used by some growers with fair success for control of mites in uncased mushroom beds. On producing mushroom beds free nicotine (40 percent), 1 part to 600 parts of water, applied once each week at the rate of 1 quart to 12 square feet of bed space by means of a sprinkling can, gave a definite increase in yield; in spite of the fact that nicotine, being a mild fungicide, retarded the growth of the mycelium and did not give a good kill of mites in the laboratory. This treatment cannot be recommended after the mushroom beds begin producing, as the mushrooms take up the nicotine.

An alcoholic extract of pyrethrum containing 2 percent of total pyrethrins, diluted 1 part to 800 parts of water and applied in the same manner as nicotine, gave a greater increase in yield than did nicotine, no damage was done to the spawn; and as this material is relatively harmless to consumers, possible poisoning is not a factor in its use. Pyrethrum used in this fashion kills relatively few mites but seems to act as a repellent. In the laboratory, spawn so treated was nearly free of mites within 2 hours.

Dichloroethyl ether and water (1:166), emulsified with gum arabic and applied as a drench as described above for nicotine, killed a high percentage of mites in mushroom beds and did not reduce the yield of mushrooms. Similar results were obtained with methyl salicylate and water (1:500). Further studies should be made with each of these materials.

### CONTROL BY THERMAL TREATMENTS

Thermal treatments include the use of boiling water, flame, or live steam. Boiling water is used as an emergency treatment on bearing mushroom beds between flushes. The beds should be allowed to dry

out somewhat, the boiling water applied until the casing soil is well soaked, and the beds again allowed to dry out to the proper degree of moisture. This treatment kills only the mites on the bed surface and in the very top layer of the casing soil, since only the upper one-fourth or one-eighth inch is heated to lethal temperature. No apparent harm is done the spawn by this treatment.

In severe infestations flame from a blowtorch is sometimes played rapidly over the surface of the beds between flushes. This treatment also kills only the mites on the surface.

With the use of live steam also, only mites on the surface of the casing soil are killed. Even to obtain this kill the steam must be applied under considerable pressure.

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